

in constructive engineering can be overcome which would otherwise have been most formidable.

Mr. William Jones read a paper on processes for the recovery of tar and ammonia from blast-furnaces fed with raw coal. The coal generally employed is what is known as Scotch splint coal; it contains on an average 40 per cent. of volatile matter and 50 to 55 per cent. of fixed carbon. The average amount of nitrogen in the coal is 1.35 per cent.; if all this nitrogen was evolved as ammonia and this again converted into sulphate, it would amount to 1422 lbs. of pure sulphate, equal to 152.8 lbs. of commercial sulphate containing 24 per cent. of real ammonia; in blast-furnace practice only 17 to 20 per cent. of the theoretical quantity, or 25 to 28 lbs. per ton, is recovered, whilst in gas-works 142 per cent. is evolved. Two methods are mainly employed: the one depending on the condensation or cooling of the gas from the blast-furnace, and the other on the treatment of the hot gas with either dilute sulphuric acid or sulphurous acid, which absorbs the ammonia in the gas; towers or scrubbers have to be used for washing the gas in both methods of treatment. The paper contains a detailed description of the various processes employed in carrying out these two methods for the recovery of by-products. The make of sulphate of ammonia from blast furnaces in Scotland has been greatly exaggerated. Even a year hence, when the whole plant being laid down will be available, the make will not exceed 4000 tons per annum. If the gases of the whole of the blast-furnaces in Scotland at present in blast were being treated for ammonia, the turn-out of sulphate of ammonia would be some 18,000 tons per annum, equal to about 22 per cent. of the present British production.

With the discussion of this paper proceedings on Wednesday began; after which Mr. J. Riley read a paper descriptive of an experimental cupola-furnace, which it is proposed to employ in connection with the open-hearth process, with the object of shortening the time employed. Many years ago Mr. Hackney tried at Landore the experiment of pre-melting the pig-iron in a cupola, whence the fluid charge was quickly and readily transferred to the melting-furnace. Instead, however, of saving three or four hours by charging fluid metal, it was found, on repeating the experiment at Hallside, that there was only a saving of about a quarter of an hour in time, obtained at the expense of the coke and labour expended at the cupola. This is due to the circumstance that during the melting of a charge in the open-hearth furnace a large proportion of the silicon and carbon is removed, leaving little more than half the carbon to be eliminated in subsequent operations. Now in the case of the fluid charges, which had been pre-melted with coke in the cupola, these changes have not taken place, and the time required to remove the impurities from the fluid metal, after being charged on the open-hearth furnace, is almost as long as that required to melt and purify the solid charge. The idea occurred to the author to substitute gaseous for solid fuel in the cupola. The gas generator has a closed grate and is dependent upon forced blast, and the air for supporting combustion in the body of the furnace is also obtained from the blower, and is heated.

The experiments made with this cupola prove that not only is there a saving in time and fuel, but that the percentage of silicon and carbon in the pig-iron and steel scraps are very much reduced, so that it is anticipated that when the fluid metal can be charged direct into the open-hearth furnace, the time for its conversion into mild steel will be greatly shortened.

This paper caused a very lively discussion, with which the proceedings on Wednesday terminated.

On Thursday amongst other papers was one descriptive of the Forth Bridge by Mr. Baker, which we print below *in extenso*.

In the afternoon of each day the members visited various steel and iron works in the neighbourhood.

THE FORTH BRIDGE¹

AS the members of the Iron and Steel Institute purpose paying a visit to the Forth Bridge works, I have been requested by the Secretary to prepare a short paper on the subject for the information of the members, and do so with pleasure.

The North British Railway Company for many years have striven hard to obtain a physical connection of their lines north and south of the Forth by means of a bridge. Twenty years ago they were authorised by Act of Parliament to build a bridge across the Forth at a point five miles above the site of that now

¹ Paper read at the Glasgow meeting of the Iron and Steel Institute by Mr. Benjamin Baker, M.Inst.C.E.

under construction, but borings 120 feet in depth showed nothing but soft silt and mud, and the bridge, which was to have been two miles in length, inclusive of four spans of 500 feet each, was luckily abandoned, as the difficulties with the foundations would have proved practically insuperable. In 1873 another Act was passed for a bridge across a narrower and deeper part of the Forth at Queensferry. At low water the width of the channel there is about 4000 feet; and the island of Inchgarvie affording a foundation for a central pier, it was possible to cross the 200 feet deep portion of the sea-way by a couple of spans from 1600 feet to 1700 feet each in the clear. Sir Thomas Bouch prepared a design for this bridge on the suspension principle, with towers 665 feet in height from base to summit, and the contract for its construction was let to Mr. Arrol. Owing to the subsequent fall of the Tay Bridge, public confidence in Sir Thomas Bouch's design was shaken, and in session 1881 a bill for the abandonment of the Forth Bridge was proceeded with. Whilst in Committee, the different companies interested, namely, the North British, Great Northern, North-Eastern, and Midland Railway Companies, ordered a final reference of the whole question to their respective consulting engineers, with the result that the abandonment bill was dropped, and the design for a cantilever or continuous girder bridge prepared by Mr. Fowler and myself, in consultation with Mr. Harrison and Mr. Barlow, was substituted for the original suspension bridge. In 1882 the necessary Parliamentary powers were obtained, and in January 1883 the works were commenced by Messrs. Tancred, Arrol, and Co., the contractors.

The total length of viaduct included in the contract sum of £1,600,000 is about 1½ miles, and there are—

2 spans of	1710	feet each.
2	"	675
15	"	168
5	"	25

Including piers, there is thus one mile of main spans, and half a mile of viaduct approach. The clear headway is 150 feet above high water, and the tops of the great cantilevers are more than 200 feet higher still. There will be about 45,000 tons of steel in the superstructure of the bridge, and 120,000 cubic yards of masonry in the piers.

Piers.—The South Queensferry main pier consists of a group of four cylindrical piers of masonry and concrete, founded by means of pneumatic caissons on the strong boulder clay constituting the bed of the Forth at this point. Owing to the slope of the clay, the caissons required to be sunk to depths varying from about 70 feet to 90 feet below high water. The diameter ranges from 70 feet at the base to 60 feet at low-water level, above which the iron skin of the caisson is replaced by a facing of Aberdeen granite. At the base of the caissons is a working chamber 7 feet in height supplied with compressed air, and electrically lighted, for the men excavating the material. This chamber was kept clear of water by a pressure of air considerably less, as a rule, than that due to the head of water outside. For example, at 90 feet below high water, when the north-east caisson had been sunk through a considerable thickness of silt, the air-pressure required to be maintained at 18 lbs. per square inch only, although at the reduced depth of 57 feet it was found convenient to work at 30 lbs. air-pressure. Three shafts and air-locks were provided for each caisson, two for the excavated material, and one for the men. The former had two horizontal sliding doors actuated by small hydraulic rams, and the skip containing the clay and boulders was hoisted up the 90-feet shaft by a steam-engine mounted on the side of the air-lock. As a rule, from 200 to 300 skips of excavated material were raised per day of 24 hours by a force of from 20 to 30 men. The maximum number of skip-loads was 363, and of men 33. The size of the skips was 3 feet diameter by 4 feet 3 inches high. Owing to the extreme hardness of the clay it was necessary to provide a certain number of spades having hydraulic rams in the handles, which, abutting against the roof of the working chamber, sliced the clay readily.

At the present time three of the South Queensferry caissons have been sunk successfully to the full depth, and the fourth and last would also have been completed but for an unfortunate accident which happened to it at the beginning of the year. By some means the caisson, which had been floated into position for some weeks, accidentally filled with water, and sank and slid forward on the mud. It is now being carefully cased in timber to admit of the water being pumped out and the caisson floated again into position.

At Inchgarvie similar pneumatic caissons are used for two out of the four cylindrical piers, and the work on both is in full progress. Owing to the slope of the rock bottom, it is necessary to cut away as much as 18 feet in thickness of whinstone rock to form a level bench for the pier at 70 feet below high water, and the most convenient way of doing this was to convert the base of the pier practically into a great diving-bell 70 feet in diameter. In this case, there being no silt over the rock, the pressure of air necessarily is that due to the depth of water outside, and somewhat sensational "blows" occur with a falling tide. Rock drills are provided, and blasting goes on in the compressed-air chamber without necessitating the withdrawal of the men.

At North Queensferry, the four main piers were built either on dry land or within timber and clay cofferdams. Above low water the whole of the main piers are built of Arbroath masonry in cement faced with Aberdeen granite, and hooped occasionally with 18 inches wrought-iron bands. The cantilever end piers, and the viaduct piers, are built of rubble, concrete, and granite in cement.

Superstructure.—Although the piers of the Forth Bridge present many points of interest, it is the enormous span and novel design of the superstructure that has attracted the attention of the engineers of the world to the work now in progress at Queensferry. The chief desiderata in the biggest railway bridge ever proposed to be constructed are durability, strength, and rigidity under express trains and hurricane pressures; facility and security of erection, high quality of material and workmanship, and economy in first cost and maintenance. These, we considered, would be best met by a steel "cantilever" or "continuous girder" bridge. Since the commencement of the Forth Bridge, American engineers, ever bold and ready, have built three cantilever bridges of considerable spans, and practical experience has confirmed our anticipations as to the advantages of the system; the Niagara Bridge, over 900 feet in length, which was manufactured and erected across the rapids in the short time of ten months, having stood all the tests of actual working in the most satisfactory manner.

In the Forth Bridge, each span of 1710 feet is made up of two cantilevers, projecting 680 feet, and a central girder connecting the same, 350 feet in length. The cantilevers are 343 feet deep over the piers, and 40 feet at the ends. The bottom members consist of a pair of tubes tapering in diameter from 12 feet to 5 feet, and spaced 120 feet apart, centre to centre, at the piers, and 31 feet 6 inches apart at the ends.

The top members consist of a pair of box lattice girders, tapering in depth from 12 feet to 5 feet, and spaced 33 feet apart at the piers, and 22 feet 3 inches at the ends. Each tube has a maximum gross sectional area of 830 square inches, and each girder a maximum net sectional area of 506 square inches. Upon each cylindrical masonry pier is bolted a bed-plate carrying a "skewback," from which spring vertical and diagonal columns and struts. The former are 12 feet in diameter, and from 368 to 468 square inches sectional area; the latter are flattened tubes. Horizontal wind-bracing of lattice girders connect the tubes forming the bottom member of the cantilevers, and similar vertical wind-bracing connects the vertical and diagonal tubes, so that the whole structure is a network of bracing capable of resisting stresses in any direction and of any attainable severity.

The rolling load provided for is (1) trains of unlimited length on each line of rails weighing 1 ton per foot run; (2) trains on each line made up of two engines and tenders, weighing in all 142 tons, at the head of a train of 60 short coal-trucks of 15 tons each. The wind provided for is a pressure of 56 lbs. per square foot, striking the whole, or any part of the bridge, at any angle with the horizon, the total amount on the main spans being estimated at no less than 7900 tons. In practice only two trains, weighing 800 tons in all, would be on this length of bridge at the same time, so the wind pressure (if such a hurricane as 56 lbs. per square foot could ever occur) would be ten times as great as the train load. Under the combined stresses resulting from the test load in the worst position, and the heaviest hurricane, the maximum stress on the steel will not exceed $7\frac{1}{2}$ tons per square inch on any portion of the structure, and on members subject to great variation in the intensity and character of stress, the maximum will not exceed 4 tons per square inch. For tubular columns and struts 34 to 37 ton steel, with an elongation of 17 per cent. in 8 inches, is specified, and for tension members 30 to 33 ton steel, with 20 per cent. of elongation. We have now

about 15,000 tons of steel delivered and worked up, and are satisfied that the quality as supplied to us by the Steel Company of Scotland and the Landore Company is admirably adapted for bridge construction. In making the tubes the plates are heated in a gas furnace and bent hot between dies in a powerful hydraulic press. A slight distortion takes place in cooling, which is corrected by pressing the plates again when cold. After bending, all four edges are planed and the plates built up into a tube. Travelling annular drill frames surrounding the tube, fitted each with ten traversing drills, bore the holes at once through plates, covers, and stiffeners, so that when again fitted in place for erection every piece comes into exact juxtaposition. Similar travelling drill frames deal with the lattice box-girders, every hole being drilled as the machine advances. Generally the plant designed by Mr. Arrol for drilling the innumerable holes in the 42,000 tons of steel-work for the main spans is of signal merit and efficiency, and well worthy the attention of practical engineers.

At the present time, although, as already stated, about 15,000 tons of steel-work is on the ground, only the approach viaduct girders and some of the bed-plates of the main spans are erected and riveted up. In a few weeks, however, the erection of the portion of the main spans over the North Queensferry piers will be proceeded with. The "skewbacks" and connecting tube will first be riveted up, and then a platform of temporary girders and planking will be constructed, and raised gradually by hydraulic rams in the four vertical 12-foot diameter columns as the work of erection and rivetting-up progresses. This platform will carry cranes and other appliances, and the men will be thoroughly protected, so that work may be carried on with as much confidence at a height of 350 feet as at sea-level. When the portion of steel-work over the piers is erected, the first bay of cantilever on each side of the same will be added, the work forming its own staging. This will be followed by succeeding bays until the cantilevers are complete, and the central girders will then be erected, probably on the same plan.

It will be observed that for certain parts of the Forth Bridge we use steel of a higher tensile strength than is at present considered admissible either for ships or boilers. This has not been done without full and mature consideration of the whole question. Our experiments showed that steel, having a tensile strength of from 34 to 37 tons per square inch, offered a decided advantage over very mild steel, when compressive stresses and the flexure of long columns were concerned. Indeed, an inferior quality of steel, such as would be used for rails, will stand compression far better than the best boiler steel or Lowmoor iron. Thus, I found a column twenty diameters in length of common Bessemer steel carry 27 tons per square inch, where one of mild boiler steel has stood but 17 tons. It would be inexpedient, however, to use inferior steel, even for the compressive members of a bridge, and therefore a high quality and high tensile resistance were indicated. Although this steel takes a temper and becomes brittle if cooled in certain ways, it will stand the ordinary Admiralty temper tests, bending to a radius of double the thickness, after being made red-hot and cooled in the usual way. In a boiler the steel plates are subject to great changes of temperature and consequent stresses from expansion and contraction. In a ship almost every plate in the hull is subject to alternate tensile and compressive stresses when amongst waves; and, further, a vessel is liable to severe alternating stresses and shocks on taking ground, dry docking, and under other circumstances. In the compression members of the Forth Bridge the steel is subject only to a steady pressure of varying intensity, and a quality of steel was adopted which combined perfect facility in working with a high resistance to compression. Although an increased tensile strength is accompanied by a decidedly increased resistance to flexure in columns and struts, the latter is not proportional to the former. If the thing were practicable, what I should choose as the material for the compression members of a bridge would be 34- to 37-ton steel, which had been previously squeezed endwise in the direction of the stress to a pressure of about 45 tons per square inch—the steel plates being held in suitable frames to prevent distortion.

My experiments have proved that 37-ton steel so treated will carry as a column as much load as 70-ton steel in the state in which it leaves the rolls, that is to say, not previously pressed endwise. It would be a matter of much practical moment to ascertain if some convenient treatment could be devised which would endow steel with this greatly increased power of resistance

to compression without injuring its resistance to tension, or its ductility, which remained unaffected by previous compression in my experiments. At least one-half of the 42,000 tons of steel in the Forth Bridge is in compression, and the same proportion holds good in most bridges, so the importance of gaining an increased resistance of 60 per cent. without any sacrifice in the facility of working, and safety belonging to a highly ductile material, can hardly be exaggerated.

Our experience has led us to the conclusion that sheared edges are a more fruitful source of fracture than partial tempering or other contingencies. All of our bent plates are made red-hot, and the effect of the shearing is thus eliminated even before planing. Those plates which are not heated have the edges carefully planed so as to leave no trace of the shearing, and we find that, whether we are dealing with 30-ton or 37-ton steel, the plates so treated stand all the desired tests. Experiments which I have made, and am still making, on the resisting power of different classes of iron and steel to repeated bendings, such as the shaft of a marine engine undergoes if the bearings get out of line, indicate that the superiority of low-tension steel is considerably greater than the increased ductility would indicate.

In conclusion I may state that the approximate value of the plant now at the Forth Bridge is 250,000*l.*, and of the work executed 600,000*l.*

SOCIETIES AND ACADEMIES

SYDNEY

Royal Society of New South Wales, June 3.—Prof. Liversidge, F.R.S., President, in the chair.—A paper was read by Mr. G. H. Knibbs on a system of accurate measurement by means of long steel ribands. The chief feature of the method of measurement is the application of such tensions to the riband as eliminate the effects of its suspension when it becomes necessary.—Mr. Law. Hargrave read a paper, notes on flying-machines, which consisted of deductions drawn from close observation of the behaviour of about fifty self-supporting flying-machines of various weights, from three-quarters of an ounce to four ounces. Sixteen models were exhibited. Mr. Hargrave stated that, although he believed the trochoided plane to be the true mechanical power used by birds in flight, he thought its rejection as a scientific truth of very trifling importance compared with the judicious variation and adjustment of the details of the models, so that rules could be laid down for work on a larger scale.

July 1.—Prof. Liversidge, F.R.S., President, in the chair.—A paper was read by Mr. H. C. Russell, B.A., on local variations and vibrations of the earth's surface.

PARIS

Academy of Sciences, August 24.—M. Bouley, President, in the chair.—Note on human locomotion; mechanism of the jump, jointly communicated by MM. Marey and G. Demeny. This first communication on the subject of human locomotion begins with the action of springing or jumping, because, although not the most usual, it is regarded by the authors as by far the simplest, and much less intricate than walking or running, in which the body executes complicate movements in the direction of the three dimensions of space. The paper is illustrated by a *chromo-photograph* showing the successive positions of legs, arms, and shoulders in a man taking a standing leap (*saut de pied ferme*); also by diagrams of two high jumps executed on the dynamograph.—Observations on the prevalence and development of pestilence and cholera in Persia, where quarantine preventive measures have never been adopted, by M. J. D. Tholozan. The author, who has had twenty-eight years' experience of the action of these epidemics in Persia, is inclined to think that the quarantine system would have proved of little or no avail in arresting their progress. The paper was followed by a few remarks by M. Larrey, also pointing at the general inefficacy of quarantine measures.—Note on M. Hirn's paper on the crepuscular lights inserted in the *Bulletin* of the Colmar Natural History Society, by M. Faye. From his observatory at Colmar the author noticed this phenomenon at an altitude far higher than that of the terrestrial atmosphere. Without deciding on the merits of the different theories advanced to explain its origin, he considers that electricity alone would be capable of retaining at such an altitude the particles of matter causing the after-

glows, whether these particles were derived from the Krakatoa eruption or from the interstellar spaces.—Observations of the new planet, 249 (discovered by M. Peters on August 16 at Clinton, New York), made at the Paris Observatory (equatorial of the West Tower), by M. G. Bigourdan.—Observations of Barnard's comet made at the Observatory of Bordeaux with the 14-inch equatorial, by M. G. Rayet.—On the theory of revolving mirrors as a means of measuring the velocity of light, by M. Gouy.—Experiments on double refraction (four illustrations), by M. D. S. Stroumbou. By a simple contrivance the author renders visible to a large audience the course of two rays, ordinary and extraordinary, in a birefringent crystal: (1) when the two facets are artificial and perpendicular to the axis; (2) when they are artificial and parallel to the axis; (3) when they are the natural facets of the crystal parallel to each other.—Note on the alcoholic derivatives of pilocarpine, by M. Chastaign.—On the transmission of pathogenetic microbes from the mother to the fetus and in the milk, by M. Koubassoff. From experiments made on the guinea-pig the author infers that the charbon virus, the bacilli of tubercular affections, and other germs of disease pass into the milk and remain there during the term of lactation, or till the death of the mother; also that the fetus nourished on such milk do not catch the respective diseases, but survive even the death of the mother; lastly, that the transmission of microbes from mother to fetus depends probably on the existence in the placenta of direct communications between the vessels of mother and fetus.—On an alkaloid substance extracted from the liquid in which Koch's microbe was cultivated, by M. A. Gabriel Pouchet. An analysis of this liquid revealed traces of the presence of an alkaloid liquid presenting outward characteristics, such as small and toxic properties, apparently identical with those detected in the dejecta of cholera patients. Should these results be definitely established, they would furnish an indirect proof that Koch's microbe is really the pathogenetic agent in cholera.—Influence of the sun on the vegetation of the spores of *Bacillus anthracis*, by M. S. Arloing.—Action of the antiseptics on the higher organisms: iodine, nitrate of silver; fourth communication, by MM. Mairet, Pilatte, and Combemale.—A note was received from M. Sacc of Cochabamba, on an extremely rich deposit of alunite lately discovered in the Peruvian Andes.

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